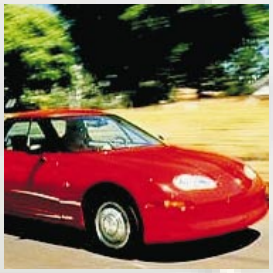

Protocol for Cooperation in the Fields of

Energy Efficiency and Renewable Energy

Progress Report

中美能源效率及可再生能源领域合作议定书进展报告

Between the Department of Energy of the United States and the Ministry of Science and Technology of the People's Republic of China

中华人民共和国科技部

与　美国能源部

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United States / People's Republic of China Cooperation in the Fields of Energy Efficiency and Renewable Energy

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美国能源部

Jointly prepared by:
Office of Energy Efficiency and Renewable Energy – Department of Energy
United States of America

and
Department of Industrial Technology – Ministry of Science and Technology
People's Republic of China

December 1999

1999 年 12 月

NOTICE

声　　明

Printed on paper containing at least 50% wastepaper, including 20% post-consumer waste
印刷纸张中至少含 50%的废纸，包括 20% 使用后废纸。

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List of Abbreviations

Technical

Measures and Units

GW	Gigawatt, 1,000 megawatts of electric power (Subscript this used to describe thermal power)
kW	Kilowatt, 1,000 watts of electric power
kWh	Kilowatt-hour, unit of electric energy
Mtce	Million Tons of Coal Equivalent, equal to 0.12276 TWh of electricity
MW	Megawatt, 1,000 kilowatts of electric power
RMB	Renminbi, domestic currency = 1 yuan used for foreign exchange
TW	Terawatt, 1,000 gigawatts
Wp	Watts-Peak, Maximum output from a solar photovoltaic panel or other device with variable output
Yuan	Unit of China money, United States $1= 8.27 Yuan

Terminology

BOD	Biological Oxygen Demand in water
COD	Chemical Oxygen Demand in water
GIS	Global Information System; digital data base on terrain and manmade surface features
PV	Photovoltaic, solid state device that converts solar energy to electricity

China Organizations

MOST	Ministry of Science and Technology
SDPC	State Development and Planning Commission
SETC	State Economic and Trade Commission
SPCC	State Power Corporation of China

United States Organizations

DOE	U.S. Department of Energy
NREL	National Renewable Energy Laboratory

技术术语缩写

量度单位

GW	相当于 100 万千瓦电功率（下标 $_{th}$ 表示火电 ）
kW	千瓦,相当于 1,000 瓦电功率
kWh	千瓦时，电能的单位
Mtce	一百万吨标准煤，等于 0.12276 TWh 电能
MW	兆瓦，相当于 1,000 千瓦电功率
RMB	人民币,国内货币
TW	太瓦，相当于 10 亿千瓦电力功率
Wp	峰瓦，太阳能光电板或其它有变化输出功率装置的最大输出功率
Yuan	中国货币的单位，1 美元= 8.27 元

术语

BOD	水中的生物耗氧基
COD	水中的化学耗氧基
GIS	地理信息系统；数字地形数据与手绘地表特征图相结合
PV	光伏，将太阳能转变成电能的固定装置

中国组织部门

MOST	科学技术部
SDPC	国家发展计划委员会
SETC	国家经济贸易委员会
SPCC	国家电力公司

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DOE	美国能源部
NREL	美国国家可再生能源实验室

Acknowledgments

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Executive Summary

This report, prepared jointly by the United States Department of Energy (DOE), and the People's Republic of China, Ministry of Science and Technology (formerly the State Science & Technology Commission (SSTC)), documents progress that has been made by both countries in areas covered by the Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy Technology Development and Utilization (hereinafter referred to as Protocol). The report focuses on the first three years of work done under the Protocol which was reviewed at the first Joint Working Group Meeting held in Washington, D.C., on November 4-5, 1998. Additional information on activities subsequent to that meeting is included where possible.

China's Energy and Environment Challenges

China is currently the world's second largest energy consumer, after the United States (about 35 quadrillion Btu in China in 1995, versus 88 quadrillion Btu in the U.S.). China is also the world's largest coal producer and consumer. Electricity generation is dominated by coal-fired plants (about 75 percent in China in 1995 versus 51 percent in the U.S.). Heavy reliance on coal has caused severe environmental pollution in China including acid rain, smog, toxic waste, water pollution, and carbon dioxide emissions. China now accounts for about 13 percent of world's carbon emissions, ranking second behind the U.S. As China's economic growth of the past two decades continues, demand for energy is expected to increase at a rate of 4-5 percent annually through 2015. At this rate, China could surpass the U.S. as the world's largest energy consumer and greenhouse gas emitter by the year 2025, according to the U.S. Department of Energy's, Energy Information Administration.

China recognizes these challenges and the need to pursue aggressive programs to support environmental and social concerns while maintaining economic and energy development. Key programs include deployment of energy efficient and renewable energy technologies to reduce reliance on coal and providing energy to the estimated 60 million habitants who live in remote, rural areas and islands which lack access to an electricity grid. China's Agenda 21 Program was developed following the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992. The program plan emphasizes use of energy efficiency, renewable energy, clean coal technology, combined cycle power plants, and nuclear power. In March 1994, China's State Council approved the Sustainable Energy Programs under Agenda 21.

Subsequently, in the Ninth Five-Year Plan (1996-2000), China adopted several ambitious national programs including the "Brightness Program," "Integrated and Comprehensive Rural Electrification," "Energy Efficient Lighting," and "Riding the Wind Program." In addition, China is implementing the Energy Conservation Law, adopted by the People's Congress on November 1, 1997. All of those programs and policies aim to use efficiency and renewable energy as a means of reducing energy intensity (the energy used to produce a unit of Gross Domestic Product) and providing least-cost electricity to remote areas, thus curtailing environmental damage.

U.S.-China Energy Efficiency and Renewable Energy Protocol

In response to an invitation from Dr. Song Jiang, Chairman of the SSTC and of China's National Climate Committee, U.S. Secretary of Energy, Hazel O'Leary led a Presidential Mission on Sustainable Energy

and Trade to China in February 1995. During that visit seven new agreements were signed including the Energy Efficiency and Renewable Energy Protocol.

The Protocol focuses on three sustainable energy goals: (1) to advance world energy security interests by helping China develop more diversified energy resources and thereby reduce its future demand for oil; (2) to mitigate environmental damage associated with rapid growth in energy demand through deployment of renewable energy and energy efficiency measures; and (3) to enhance U.S. industry competitiveness in China's energy market.

Activities under this Protocol also support goals of the U.S.-China Forum on Environment and Development discussed at the second meeting of the Forum, which was co-chaired by U.S. Vice President Al Gore and Chinese Premier Zhu Rongji on April 9, 1999, in Washington, D.C. The Forum includes an Energy Policy Working Group that is co-chaired by the DOE and the SDPC, covering many facets of various agreements in areas including: renewable energy, energy efficiency, oil and gas, clean coal technology, coal mine methane, and other topics.

The first meetings of the Forum on Environment and Development and its Working Groups were in March 1997 in Beijing. Building on successful initial discussions in the areas of energy and environment, in October 1997, then Secretary of Energy Federico Peña and SDPC Minister Zeng Peiyan co-signed a joint statement, the "Energy and Environment Cooperation Initiative." The Initiative is aimed at strengthening bilateral cooperation with a view toward helping China meet its energy needs in a way which advances local, regional and global environmental concerns, including global climate change. The Initiative also identified three areas as priority areas for cooperation: urban air quality; clean energy and energy efficiency; and rural electrification.

The Protocol advances the goals of the U.S.-China Forum and the Energy and Environment Cooperation Initiative by promoting energy efficiency and renewable energy and specifically by advancing these applications to help meet China's rural electrification and environmental goals. Cooperation under the Protocol may include: technical assistance, training, policy analysis, resource and market assessment, and information exchange. The Protocol now has six annexes, four of which relate to renewable energy, one to energy efficiency, and one to electric and hybrid-electric vehicles.

Status of the Protocol and Accomplishments

Annex I, Rural Energy Development – signed with the Ministry of Agriculture (MOA) on June 27, 1995, focuses on the use of village scale renewable technologies such as biogasification, wind, solar photovoltaics, and wind/solar hybrid systems to provide energy or electricity to China's rural areas. Cooperative activities include pilot projects for rural electrification, training and personnel exchanges, and a U.S.-China Rural Electrification Workshop. Three successful projects, which can be replicated in other areas of China, have laid a solid foundation for China's rural energy development.

- **Gansu Solar Home System Project** – The U.S. Solar Electric Light Fund (SELF) and the Gansu Solar Electric Light Fund (GSELF), supported by DOE's National Renewable Energy Laboratory (NREL) and MOA, completed installation of 320 photovoltaic (PV) solar home systems in 1998. In addition, ten schools were equipped with U.S. made, 53-watt PV systems. As a direct result of Protocol projects, another 275 systems have been installed by GSELF with support of the Gansu Provincial government. This success led the MOA to expand its solar home system project to

10,000 households in six northwestern provinces. A market characterization survey, analyzing social and economic factors which impact the sustainable development of PV technology, is currently being conducted in Qinghai and Xingjiang provinces.

- **Rural Biomass Collaboration** – DOE/NREL collaborated with MOA to develop an assessment of biomass resources, a description of China's technological capability in some of the biomass conversion areas, and an initial techno-economic assessment of potentially useful biomass and bioenergy systems. Reports on this initial data and research were published in China as a bilingual set of three books titled: (1) "Assessment of Biomass Resource Availability," (2) "Biomass Energy Conversion Technologies in China," and (3) "Design for Market-Oriented Development Strategy of Bioenergy Technologies," and as a CD-ROM.

- **Inner Mongolia Hybrid Household Project** – The University of Delaware and DOE/NREL completed case studies on household and village power systems, including technical performance and economic analyses of 41 households and three villages in 1997. Subsequently, in a pilot project between DOE/NREL and the Inner Mongolia New Energy Office, 96 household PV/wind (450-500 watt) systems were installed initially, with an additional 125 systems installed in 1999, and 120 in the year 2000. The U.S. is providing U.S. PV modules for this project. As a result of this activity, local officials in Dongwu County have completed a feasibility study and plan for 4,000 hybrid systems to be installed over the next five years.

Annex II, Wind Energy Development in China – signed with the Ministry of Electric Power (now SPCC) on October 25, 1996, focuses on accelerating sustainable large-scale development of wind power in both grid-connected and off-grid village power applications in China. With support from DOE, NREL, and the U.S. wind industry, the objectives of this annex are to demonstrate the technical and economic feasibility of advanced wind energy technology and to enhance its commercialization potential for the benefit of both countries. Cooperative activities include resource assessment, utility wind power plant analysis, a finance workshop, wind/hybrid mini-grid analysis, project development and personnel exchanges in training programs. Major projects include:

- **Wind Resource Assessment and Mapping** – The DOE/NREL, in partnership with the U.S. Environmental Protection Agency (EPA), completed a southeast China wind resource assessment and mapping in 1998 in the provinces of Jiangxi, Fujian, and the eastern half of Guangdong. The mapping products are designed in highlight areas that are expected to have a favorable wind resource and where specific wind energy projects are likely to be feasible. The most attractive wind resource is found along the coastal area and on the offshore islands, particularly along the coast of Fujian, where many excellent sites were identified by the mapping process. Verification of wind resource estimates is continuing, using local electric power bureaus' data and digital data collected from nine anemometers supplied by the U.S.

- **Xiao Qing Dao Village Power Project** – DOE/NREL and SPCC are currently developing a pilot project using a wind/diesel/battery system to electrify 120 households on an island called Xiao Qing Dao located in the Yellow Sea off Shandong Province. The DOE will provide four 7-kW wind turbines, batteries, a 40-kW inverter, and spare parts. The SPCC will provide the diesel generator, the turbine towers, foundations, buildings, and the distribution systems. In addition, the SPCC will collect performance and operational data for DOE/NREL and the project is estimated to be commissioned in 2000.

Annex III, Energy Efficiency – signed with the State Planning Commission (now SDPC) on October 25, 1996, focuses on ten areas: (1) energy policy; (2) information exchange and business outreach; (3) district heating; (4) cogeneration; (5) buildings; (6) motor systems; (7) industrial process control; (8) lighting; (9) amorphous core transformers; and (10) finance. Both sides established 10 teams composed of representatives from industry, government agencies, and energy association to address barriers and opportunities. An Energy Efficiency Steering Committee Meeting, co-chaired by DOE and SDPC, was held in 1997 to evaluate progress made in the past and to discuss future plans. Major activities include:

- **Electric Motor Systems** – A DOE delegation conducted a Motor Challenge workshop on electric systems in Beijing in May 1998, and a second workshop on pumping systems was held in November 1999. The SDPC plans to make this a national program in China.

- **Energy Efficiency Policy** – China is currently implementing its Energy Conservation Law that was signed on November 1, 1997. At China's request, U.S. experts discussed implementation of U.S. energy efficiency laws, policies, and standards, at a workshop in Beijing in December 1997.

- **Energy Efficient Buildings** – An action plan for cooperation on energy efficient buildings has been prepared.

Subsequently, a second Energy Efficiency Meeting was held in June 1999 in Beijing. The results of that meeting were not available in time to be included in this report.

Annex IV, Renewable Energy Business Development – signed with the State Economic and Trade Commission (SETC) on October 25, 1996, is implemented by the Center for Renewable Energy Development (CRED), an organization under China's SDPC. This Annex focuses on renewable energy policy analysis and development, information exchange, business outreach, training, and project finance. Activities include:

- **Provincial Renewable Business Profiles** – Two business development studies have been performed in partnership between CRED and NREL. The first study conducted in late 1996, described factors that influence the deployment of renewable energy in six provinces (Gansu, Inner Mongolia, Qinghai, Shangdon, Xinjiang, and Zhejiang). The second study conducted in 1998, included four additional provinces (Guangdong, Jiangxi, Jilin and Yunnan) and discussed changes that have been made under China's government restructuring.

- **Chinese PV Industry and Technology Assessments** – An evaluation of local PV businesses and applications was conducted in 1998 and will be published in early 2000. This evaluation includes local interviews with a large number of PV cell and module manufacturers, distributors, and integrators. A review of the status of PV technology and industry development in China was conducted by CRED and U.S. consultants.

Annex V, Electric and Hybrid-Electric Vehicle Development – signed with the Ministry of Science and Technology (MOST) on November 18, 1997, is to promote cooperative activities on information exchange; economic, environmental, and policy studies; and training.

- **Information Exchange** – Two major collaborative visits occurred in 1997 and 1998. Both sides have agreed that information exchange will be the top priority for the Phase I cooperation. Thus far,

many publications and materials regarding electric vehicle infrastructure requirements such as building codes and safety standards have been sent to the MOST. In 1999, a web site is planned to disseminate additional information about electric and hybrid-electric vehicles.

Annex VI, Geothermal Production and Use – signed with the Ministry of Science and Technology (MOST) on November 18, 1997, outlines cooperation in the areas of geothermal electricity generation technologies, geothermal direct use, and geothermal heat pump infrastructure development.

- **Geothermal Drilling Assistance** – DOE provided technical assistance in the areas of drilling technologies and a geophysical survey, to the Tengchong Geothermal Project in Yunnan Province in September 1998, where China intends to build a 10-MW demonstration geothermal power plant.

- **Geothermal Heat Pump Project** – China has proposed using geothermal heat pump (GHP) technology for three demonstration sites (Daqing, Shanghai, and Guangzhou) in three commercial buildings totaling 3.4 million square feet. DOE has agreed to provide technical assistance in feasibility studies and training in exchange for China's commitments to purchase U.S.-made equipment for the project. A comprehensive feasibility study using GHP systems in three temperature zones in China was completed in August 1999.

Conclusion

The United States and China are the two largest energy consumers in the world, and have mutual interests to develop bilateral cooperation, which can build a partnership in achieving common energy security, environmental, and economic goals. Much progress has been made in developing the Protocol Agreement into a framework for cooperation and in the research and development work aimed at accelerating the introduction of renewable energy and efficiency technologies in China. Six technical annex agreements have been developed and are underway. Through these agreements, there have been numerous valuable information exchange visits involving government and industrial firms from both countries. More than 30 U.S. companies are discussing or actively developing business activities with counterpart organizations in China. Pilot projects involving solar, wind, and geothermal energy; electric vehicles; and efficiency technologies are being deployed or planned, either directly under the Protocol Agreement or indirectly as a result of contacts or technical assistance. One joint venture agreement has been signed and other commercial ventures are being developed that should lead to increased economic cooperation and trade. The results of the Protocol activities will lead to reduction of greenhouse gas emissions; opening new, clean, and sustainable energy sources; improve energy efficiency; support rural electrification; and will encourage mutually beneficial business development.

1.0

Introduction and Background

On February 25, 1995, the United States Department of Energy (DOE) and the State Science and Technology Commission, now the Ministry of Science and Technology (MOST), of the People's Republic of China, signed a Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy Development and Utilization. Since then, cooperative activities have been defined with other Chinese government agencies, and six specific Annexes to the Protocol have been developed and are now operating.

The Protocol grew out of a strong concern in both countries about environmental and sustainability issues which result from increasing energy demand worldwide and in China specifically. Bilateral scientific and technological cooperation should encourage clean energy use and support sustainable development, resulting in mutual benefits to both countries in increased trade and economic development and energy security.

Results from the Protocol are benefitting both countries. Information is being exchanged for new and advanced technologies involving solar, wind, biomass, energy efficiency, transportation, and geothermal technologies. For selected technologies, mutually beneficial technology exchange is resulting in the deployment of pilot projects in China. These efforts support the goals of using clean energy and sustainable development. More than 30 industrial firms in United States and an equivalent number in China are involved in Protocol activities, resulting in good prospects for new business development and joint ventures. Since the program began in 1995, both countries have spent approximately $2 million USD, and are already achieving environmental benefits and business development results.

This report represents the first progress report on work underway in the areas of renewable energy and energy efficiency under the Protocol Agreement. Specific topics discussed in the report include activities planned, underway, and completed in the following areas: Annex I on Rural Energy Development, Annex II on Wind Energy Development, Annex III on Energy Efficiency, Annex IV on Renewable Energy Business Development, Annex V on Electric Vehicle and Hybrid-electric Vehicle Development, and Annex VI on Geothermal Energy Production and Use.

In October 1997, in conjunction with the first Summit meeting between President William Clinton and President Jiang Zemin, then U.S. Secretary of Energy, Federico Peña and Zeng Peiyan, Executive Vice-Chairman of China's SDPC, signed a joint statement called the "Energy and Environment Cooperation Initiative." The joint statement supports the goals of the U.S.-China Forum on Environment and Development, co-chaired by Vice President Al Gore and Premier Zhu Rongji, in advancing environmentally sound responses to help meet China's energy needs in a way which addresses local, regional and global environmental concerns, including climate change. The goals of the five-year Initiative are to strengthen bilateral cooperation and advance the role of the private sector in China's energy development through enhancing technical cooperation, to promote reforms and improvements in energy policy and investment climate, and to encourage private sector investments. The Initiative is implemented through established protocols and agreements, including the Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy. Priorities for cooperation identified in the Initiative are: urban air quality, clean energy sources, energy efficiency, and rural electrification.

Energy and environmental issues were again discussed during the visit of President William Clinton to China in late June 1998. President Clinton pointed to the importance of this area in a speech on the environment presented during his visit to Guilin, China on 2 July 1998. He said, "In October at our summit,

President Jiang and I oversaw the beginning of a joint initiative on clean energy. This week we have made important new progress. We will provide China assistance to monitor air quality. We will increase our support for programs that support renewable energy sources to decrease China's dependence on coal."

As a result of those discussions and meetings with various Chinese government agencies, the DOE agreed to continue support for the Protocol and for renewable energy bilateral cooperation during the 1998 and 1999 Fiscal Years. Work under the six Annexes to the Energy Efficiency and Renewable Energy Agreement includes training, workshops, and business development activities for wind, solar, biomass, geothermal, electric vehicles, rural electrification, and energy efficiency. Details on these programs are discussed in this Report.

The first Protocol Working Group Meeting was held in Washington, D.C., on November 4-5, 1998. This meeting was co-chaired by Shi Dinghuan from the Chinese Ministry of Science and Technology and Allan Hoffman from the U.S. Department of Energy. In his welcoming address, Brian Castelli from the DOE, Office of the Assistant Secretary for Energy Efficiency and Renewable Energy, noted that this was the first meeting of a joint working group between the two governments aimed at developing new energy sources that are both environmentally beneficial and supportive of sustainable development objectives for energy use. The meeting reviewed progress under the Protocol and laid out plans for the future. See Figure 1. The Chinese delegation also visited several industrial renewable energy project sites in California.

Figure 1. U.S. DOE and Commercial Renewable Energy Project Sites in China

2.0

Why China is Interested in Renewable Energy and Efficiency Technologies

China has abundant renewable energy resources and is aware of its environmental problems and energy supply issues. China's energy conservation efforts began in the early 1980s, mainly to address energy shortages throughout the country. In 1990, the National Climate Coordinating Group was created to study policy issues and interagency coordination. Subsequently, China's Agenda 21 Program [Reference 1] was created, defining a strategy to lead China on a sustainable development path in the 21st century. Significant progress has been made on the Agenda 21 Program, which helped with work under the US-China Protocol.

In China's Agenda 21 Program, Chapter 13 was on "Sustainable Energy Production and Consumption" and included sections on both developing renewable energy resources and improving the efficiency of energy use. The part of the Program on the development of new and renewable energy included a detailed estimate of available resources, specific development objectives, and activities needed to achieve them. Following are examples of renewable energy sources and use [1 and 2]:

- In 1993, biomass resources, in the form of crop residues, firewood, and other kinds of organic wastes, supplied about 260 million tons of coal equivalent (Mtce). In rural areas, these fuels supply 44 percent of the overall energy consumption and 69 percent of the energy used in rural households. Bioenergy potential, in the forms of solid, gaseous, and liquid fuels, is largely unused, especially in the agronomous regions in the eastern and southern provinces.

- Wind power resources are estimated to be 1,600 GW, about 10 percent of which is exploitable; at the end of 1998, 223 MW of wind power plants were operating in China. The best wind sites are in northern provinces and in coastal areas.

- Geothermal energy resource potential is yet to be fully explored; known reserves are equivalent to 3,000 Mtce and about 0.3 Mtce is currently developed and in use.

- The best solar resources are widely distributed over more than six million square kilometers, especially in the northern and western provinces and some coastal areas in south China. Many sites have annual sunshine over 600 kilojoules per square centimeter ($kJ/cm^2/yr$). This is comparable to the best solar sites in the U.S.

In 1995, there was increasing concern about the environment and there were many separate groups and agencies developing new and renewable energy technologies, under the Sixth Five-Year Plan. These R&D efforts were summarized by the Chongqing branch of the Institute of Scientific Information of China, with data from MOA, SETC and SSTC. This information was published in a book [2] that was widely distributed in and outside China and served as the basis for work done under subsequent Five Year Plans.

Agenda 21 also focused attention on improving energy efficiency and conservation. These efforts have lead to big improvements in energy efficiency. Energy intensity, measured by primary commercial energy consumption per unit of GDP, has dropped 50 percent since 1980, or 4.5 percent per year. However, China's energy intensity is still three times higher than the U.S. [3] and further improvements in efficiency are urgently needed.

China's primary energy demand has doubled since 1980, with the energy consumption shifting toward electricity and gaseous fuels. Except for the recent downturn, China has been experiencing major economic expansion, similar to the general and rapid economic growth occurring throughout the Pacific Rim countries of Asia. Growth in China's GDP between 1980 and 1990 averaged 9.5 percent. GDP growth peaked in 1992 and 1993 at 13 percent per year, with growth in the industrial sector of some selected "special economic zones" in southern China more than 20 percent per year. More recently, growth has moderated. In 1998, China's real GDP grew 7.8 percent, which is consistent with the government goal of 8 percent annual growth projected to continue through 2015. China's restraint on economic expansion has been effective in controlling inflation, which was estimated to be 5 percent in 1997, -0.9 percent in 1998, and 2.5 percent in 1999. Both controlling inflation and significant GDP growth are expected to continue to be government policy goals for the foreseeable future [4 and 5].

Economic expansion results in many stresses and strains on the Chinese government and industrial infrastructure. Until recently, energy related challenges included: increased demand for electricity and lagging power plant and electricity grid system construction; need for coal, gas, or other energy sources and the means to mine, transport, and process these fuels; increased fuel consumption and the resulting air and water pollution; and unprecedented need for venture capital and commercial financing balanced by concerns about financial stability and balance of trade. Currently, China's electric power industry is experiencing an oversupply situation, due in part to slower economic growth as a result of Asian economic problems and to over building power plants in some areas. Renewable energy development and energy efficiency affect some of these issues in ways that are discussed below.

Concurrent with economic expansion was a need for new electrical generating capacity, both to meet new needs for industry, commerce, and a growing middle class of consumers and to fill a persistent gap between supply and demand. There was and still are chronic shortages of electricity in rural regions of China and one-third of the country lacks comprehensive grid coverage. In order to meet the need for new energy, the SPCC, in Beijing, supported an aggressive program of new power plant construction, with a goal of installing an additional 16 GW of new electrical generating capacity annually over the period from 1995 to 2000 [4]. This rate of expansion has at present been curtailed (1999) but new electrical generating capacity additions can be inevitably expected in the future.

Most of the near term planned electricity generating capacity expansion for China is expected to be met using coal-fired steam turbines in the 300 MW to 600 MW range, greatly increasing the reliance on coal for electricity production in the near future. Coal is gaining as the primary commercial energy source in China, rising from 74 percent in 1980 to 78 percent in 1995, compared to 24 percent worldwide in 1996 according to the International Energy Agency. Thus, China is uniquely dependent on a single energy source and is second only to the United States in coal consumption. Electrical generation is mainly from coal (about 75 percent), but consumes only 29 percent of coal burned in China today. By the year 2010, the World Bank projects that 40 percent of the country's coal production will be used to generate electricity. Coal production in China today is about 1.2 billion tons per year [3]. Together China and U.S. consumed more than half of the coal used worldwide for electricity production during 1996, according to the International Energy Agency [http://www.iea.org/stats].

Reliance on coal comes at a high price. Together coal and oil represented 93 percent of commercial energy use in China in 1991, producing more than 600 million tons of CO_2 emissions, or about 10 percent of the world's total. Coal burning produced 85 percent of China's total CO_2 emissions and 87 percent of total NO_x emissions in 1991. The primary cause of urban air pollution in China is coal combustion for space heating. Pollution concerns are not limited to mainland China. For example, the Ministry of International Trade and Industry in Japan announced in 1994 that it will support several reconstruction projects in the city of Shenyang in Liaoning Province in China, to help reduce acid rain in Japan.

Air pollution problems in China, which are some of the worst in the world, are further aggravated by rural households burning coal for heat and cooking, along with inefficient combustion of 173 million tons of fuel wood and 298 million tons of dry crop straws and stalks. Urban air pollution from vehicles, in the form of hydrocarbons, carbon monoxide, and nitrous oxides, is also increasing with vehicle registrations expanding 12-14 percent each year since the late 1970's [3].

Coal is also an infrastructure burden. More than 50 percent of China's rail transportation is used to transport coal from the production centers in the north and west regions of the country to the densely populated areas in the east and south. Reliance on coal for electricity production has forced China's strategic planners to incorporate major infrastructure projects in their electric capacity expansion plans for new railroad and coastal port facilities, and the building of power plants at coal mine sites (mine-mouth plants) with power transmission over several major new east-west and north-south transmission line corridors [5].

China's petroleum industry is going through major changes and facing large increases in consumption, mostly in the transportation sector. Since 1993, consumption of oil has exceeded domestic production and China has been a net oil importer. The 1998 reorganization of the two state owned oil and gas corporations, strengthened control over the two vertically integrated regional entities [4].

There is also a need for rural electrification. In 1998, there were 60 million people living below the poverty level in China, with most having no access to electricity. To accelerate the process of alleviating this abject poverty and improve the quality of life for these people, one effective measure is to utilize the rich renewable energy resources. In many cases, wind and solar energy resources are abundant in rural regions of China with urgent energy needs and a lack of conventional electricity supply grid.

Not surprisingly, there is a significant and growing interest in China in developing renewable energy and energy efficiency technologies to help meet energy demands and mitigate environmental problems. China has an abundance of renewable energy in the form of biomass, hydro, solar, wind, geothermal, and ocean tidal resources. China is already one of the world's largest users of renewables, primarily in the form of biomass and hydroelectric power. The central government in Beijing through various commissions and ministries has active programs for developing renewable energy in all of the areas mentioned above.